AD-A278 364

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

...er response, including the time for reviewing instructions, searching existing data sources, ...of information. Send comments regarding this burden estimate or any other aspect of this ...Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson ...nd Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
ANNUAL 30 Sep 92 TO 29 Sep 93

4. TITLE AND SUBTITLE
EYE MOVEMENTS AND VISUAL INFORMATION PROCESSING

5. FUNDING NUMBERS
AFOSR-91-0342
61102F
2313
CS

2

6. AUTHOR(S)
Dr Eileen Kowler

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Dept of Psychology
Busch Campus
Rutgers University
New Brunswick, NJ 08903

8. PERFORMING ORGANIZATION REPORT NUMBER
AFOSR-TR- 94 0143

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NL
110 Duncan Avenue, Suite B115
Bolling AFB DC 20332-0001

Lt Col Collins

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release;
distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

When we look around a natural environment the eye is directed toward objects we select. We seem to do this task accurately and effortlessly. Yet, even such a simple task presents real problems for the oculomotor system, namely, to select the relevant target from the detailed background so that only information contained in it influences the line of sight and to spatially-pool informationin the selected target so that the line of sight lands at a single position within the selected target. We have found that: (1) the saccadic target is designated by means of selective perceptual attention, which means people cannot prepare to look to one target while accurately perceiving targets elsewhere, and (2) there is a highly-accurate spatial pooling process which can direct the line of sight to precise positions within large targets. The results show that the oculomotor system is capable of extremely rapid and effective scanning. The procedures humans use to accomplish this task may prove useful for the guidance of robotic systems which need to move about in patterned visual environments.

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
(U)	(U)	(U)	(UL)

AFOSR-TR- 94 0143

TECHNICAL REPORT. October 1, 1992 - September 30, 1993.

PI: Eileen Kowler
Department of Psychology
Rutgers University
New Brunswick, NJ 08903
tel: 908-932-2086. Fax 908-932-2263
email: kowler@zodiac.rutgers.edu

Grant AFOSR 91-0342 "Eye movements and visual information processing"

ABSTRACT

When we look around a natural environment the eye is directed toward objects we select. We seem to do this task accurately and effortlessly. Yet, even such a simple task presents real problems for the oculomotor system, namely, to **select** the relevant target from the detailed background so that only information contained in it influences the line of sight and to **spatially-pool** information in the selected target so that the line of sight lands at a single position within the selected target. We have found that: (1) the saccadic target is designated by means of selective perceptual attention, which means people cannot prepare to look to one target while accurately perceiving targets elsewhere, and (2) there is a highly-accurate spatial pooling process which can direct the line of sight to precise positions within large targets. The results show that the oculomotor system is capable of extremely rapid and effective scanning. The procedures humans use to accomplish this task may prove useful for the guidance of robotic systems which need to move about in patterned visual environments.

Summary of goals and approach

Human beings are confronted by far more visual information than they can deal with in a single glance. One of the chief limitations on our visual abilities is our acuity: We can only discern fine details of images located in a small, central retinal region known as the fovea. For this reason, scanning eye movements are critical for apprehending even ordinary visual scenes. Their importance increases dramatically for visually-demanding tasks, such as reading or search, where enormous amounts of fine detail are presented at one time.

There are two components to scanning eye movements. First, the observer has to decide where to look. Second, she has to be able to execute the eye movement that carries out the decision. Our research focuses on the second question. We want to know how the decisions are translated into action.

We can specify this problem more precisely. Suppose you decide to look at the face of someone seated nearby. Your chosen target, the face, is large, but the line of sight must land at one particular place within it. Yet, we are not usually not aware of choosing the precise landing position (the tip of the nose, perhaps). How is the landing position determined?

We have been studying a laboratory version of this task in which observers have to look at a large, but simple, eccentric target, such as an outline drawing of a circle or a cluster of random dots. We found that, providing the intent is to "look at the form as a whole", rather than at a particular place within it, the line of sight lands, reliably, near the center-of-gravity of the form. Moreover, we can increase the size of the target from a small point to a large form and neither the accuracy nor the precision of the saccadic landing positions suffer. This tells us that there is some internal process that computes the central landing position by pooling information over space in an effortless, automatic fashion. We are now studying more elaborate target configurations (spatially-filtered images, for example) in collaboration with researchers at SRI in Princeton (Bergen and Lubin) to find out what processing steps the visual system uses to pool spatial information and compute the central landing position. The pooling may, for example, be carried out only on some of the information in the target, such as its edges or perhaps its lower spatial frequency components.

There is a second component to our research. Accurate and precise aiming of the line of sight to the chosen targets requires that the spatial pooling referred to above encompasses only visual information in the selected visual targets. Irrelevant background information should not be included. One way that we might do this is by making use of our capacity to shift spatial attention to some portions of the visual field at the expense of others. "Spatial attention" refers to our internal processing resources, which can be assigned, at will, to different objects or different locations. It is well known that allocation of attention affects perceptual abilities. We have shown that it affects saccades as well. We found that perceptual recogntion is enhanced, albeit briefly, at the goal of the saccade right before the saccade is to occur. We did this in experiments that required subjects to try to identify a target in one place while at the same time programming the saccade elsewhere. We found they couldn't do both tasks at the same time as well as they could do them one at a time: either saccadic latency or perceptual identification suffered. Surprisingly, modest increases in saccadic latency were sufficient to allow accurate perceptual identification of a target remote from the saccadic goal. We draw two conclusions from these results. First, that saccades require some shift of spatial attention to the target, and this is how we direct the line of sight toward chosen details without it being dragged off in the direction of irrelevant details. Second, the attentional requirements of saccades are relatively modest. In a brief fixation pause between saccades we may be able to mentally inspect several locations in the visual display, perhaps evaluating which we will look at, with no important cost in either saccadic or visual performance.

There are three long-range implications of these results:

First, by specifying both the attentional requirements of saccades and the processing steps of spatial pooling, we facilitate the attempts of neurophysiologists to understand how the brain performs these tasks. In particular, our results may aid in the interpretation of single unit recordings from neural sites known to be active before saccades.

Second, we find both in the spatial pooling and the saccades/attention task surprisingly good performance with relatively little effort exerted by the subject. Our oculomotor system appears to be well suited to handle the demands of even complex scanning tasks. This means the primary limit on effective processing will be cognitive (target selection and interpretation) and not visual-motor. Our visual motor system is an excellent tool to accomplish the required tasks.

Third, the same problems that confront humans who have to scan visual displays also confront robots. To the extent that attentional allocation and spatial pooling provide useful solutions for humans, these same processing steps may lead to new effective solutions for guidance of robotic scanning systems.

Papers:

He, P. and Kowler, E. (1991). Saccadic localization of eccentric forms. Journal of the Optical Society of America, A, 8, 440-449.

Kowler, E., Pizlo, Z., Zhu, G.L., Erkelens, C., Steinman, R.M., and Collewijn, H. (1991). Coordination of head and eyes during the performance of natural (and unnatural) visual tasks. In The Head-Neck Sensory Motor System, (Edited by Berthoz, A., Graf, W., and Vidal, P.P.) Oxford University Press, N.Y .

Collewijn, H., Steinman, R.M., Erkelens, C.J., Pizlo, Z., Kowler,

E., and VanderSteen, J. (1992). Binocular gaze control under free-head conditions. In Vestibular and Brain Stem Control of Eye, Head and Body Movements. (Edited by Shimazu, H. and Shinoda, Y.) Springer Verlag.

He, P. and Kowler, E. (1992). The role of saccades in the perception oftexture patterns. Vision Research, 32, 2151-2163.

Epelboim, J. and Kowler, E. (1993) Slow control with eccentric targets: Evidence against a position-corrective model. Vision Research, 33, 361-380.

Kowler, E. and Blaser, E. (1994) The accuracy and precision of saccades to small and large targets. Ms under review.

Kowler, E., Anderson, E. and Dosher, B. (1994) The role of attentional shifts in the programming of saccades. Ms nearing completion. Submission expected by 3/1/94.

Talks:

Steinman, R.M., Collewijn, H., Kowler, E., Erkelens, C., Pizlo, Z. and Vander Steen, J. Free-headed gaze shifts between nearby targets are accurate. Association for Research in Vision and Ophthalmology, May, 1991.

Kowler, E. and Blaser, E. The spatial precision of saccades. Association for Research in Vision and Opthalmology, May, 1992.

Kowler, E., Dosher, B., Srinivasan, P. and Blaser, E. Saccades and attention. Association for Research in Vision and Ophthalmology, May, 1993.

Kowler, E., Dosher, B. and Anderson, E. The role of attention in the programming of saccades. Psychonomics Society, November, 1993.

Kowler, E., Dosher, B. and Anderson, E. Eye movements in patterned environments. Invited talk at the symposium "Eye movements in reading", Wenner-Gren Center, Stockholm, January, 1994.

Colloquia:

Center for Adaptive Systems, Boston, University, March, 1991. "Eye movements in the natural world."

Department of Psychology, Rutgers University, NewarkCampus, March, 1992. "Eye movements in the natural world."

Center for Visual Science, University of Rochester, March, 1992. "Gaze shifts in natural environments."

David Sarnoff Laboratory, SRI, Princeton, NJ, April, 1992. "Gaze shifts in natural environments."

Specific accomplishments and work in progress:

Saccadic accuracy and precision: We studied saccades to single point and form targets in an attempt to establish the best possible accuracy and precision of saccades. Study of such a basic question was necessary because the of the prevailing belief that saccades are inaccurate, undershooting the target by about 10%. We found no such undershoots provided that subjects are instructed to be accurate. Moreover, accuracy and precision were remarkably good, with saccades on average missing the target by only 1% of eccentricity and SD's of landing position only 6% (a precision that is similar to one of our most precise perceptual skills, namely, judgment of relative target location). Surprisingly, neither accuracy, precision nor latency were impaired by large increases in target size, showing that there must be a spatial pooling mechanism that computes, with great precision, a central landing position within eccentric objects. (Kowler and Blaser, 1994)

Saccades and attention: We looked at the link between shifts of attention and shifts of the line of sight. Our goal was to find out whether attention must be drawn to the locus of the saccade, or, alternatively, whether it is possible to attend one object and simultaneously prepare to look somewhere else. We performed several "dual-task" experiments (concurrent measures of saccades and perception) in which subjects had to look at a target (a letter in a ring of 8 letters) while at the same time identifying another letter at the designated locus of the saccade or at another location. The display disappeared before the saccade occurred to guarantee no change in the retinal eccentricity of the letters. Letter identification was better at the saccadic goal than elsewhere. But surprisingly, identification at the non-goal locations could be improved substantially with little or no cost to either saccadic latency or accuracy. Reaching optimal levels of perceptual identification required latency increases of 50-75 msec. Thus, saccades require allocation of attention to the target, but the attentional requirements of a saccade are modest. The results suggest a dissociation between systems that determine the saccadic goal (controlled by means of selective attention) and those that issue the "go" signal to trigger the saccade. One way for these two systems to work together as effectively as our results show they can would be to allow the triggering system access to information about the current locus of attention and, in addition, to another signal specificing the intended saccadic goal. This would allow the saccade to be launched as soon as the locus of attention coincides with the pre-selected goal. Such a scheme would allow rapid and accurate scanning while minimizing the need for time-consuming decisions "on-line" about when and where to aim the eye. (Kowler, Anderson and Dosher, 1994).

Saccades to dot clusters: We studied the accuracy and precision of saccades to small (60') clusters of random dots. Our goal was to begin to characterize the spatial pooling process, which we believe (He and Kowler, 1989, 1991) computes the saccadic endpoint automatically within the region of spatial attention. In these experiments both the spatial position of the outermost boundary of the cluster and the center of gravity of the cluster were varied independently. We found that saccades were directed with great precision to the center of gravity of the cluster. These results suggest an averaging process that pools information in a selected target and does not give special weight to outer boundaries. We are continuing this study using random dot fields in order to map the size and shape of the region over which automatic spatial pooling can occur, in effect, finding an oculomotor "receptive field" analogous to visual receptive fields (Kowler, Sharma, McGowan and Chubb).

Filtered stimuli: Another way to characterize the spatial pooling process is to study stimuli with specially chosen spatial characteristics. We plan to use stimuli that are filtered so that they contain only a single spatial frequency. We want to know whether the spatial-pooling process is restricted to only certain frequency bands. If so, then removal of these frequencies should disturb saccadic accuracy and precision. We will also vary stimulus contrast. Insensitivity to contrast over a broad range suggest some mechanism must exist that compares the output of a number of similarly-tuned filters. These experiments are in an early stage and are being carried out in collaboration with Drs. James Bergen and Jeff Lubin at the Sarnoff Research Laboratory, SRI, Princeton, NJ. (Sharma, Lubin, Bergen and Kowler).

The attentional field: These experiments follow the work on saccades and attention described above and they represent an attempt to better characterize the spatial limits of attentional regions. We designate two eccentric locations via central cues and then test perceptual identification for targets at these locations. If there are limits to the size of an attentional region, then the perceptual performance will be better when the two cues fall in the same attentional region. Alternatively, attention may be "object-based" in which case the spatial locus of the cues will not be important. These experiments also provide a perceptual analog to the experiments on saccades and attention described above in that they will allow us to find out whether the costs of dividing attention between a perceptual and saccadic target also obtain when attention is divided between two perceptual targets. (Bahcall, Anderson, and Kowler)

AIR FORCE OF SCIENTIFIC RESEARCH (AFSC)
NOTICE OF TRANSMITTAL TO DTIC
This technical report has been reviewed and is
approved for public release IAW AFR 190-12
Distribution in unlimited.
Joan Boggs
STINFO Program Manager